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## NOTES ON THE GEOLOGY OF WYOMING AND COLORADO TERRITORIES.

## No. 2.

BY F. V. HAYDEN.

Before describing the geological character of the Laramie Plains and the country to the west of it, I will attempt to present a resumé of the physical geography of that very interesting region. If we look at the profile of the route constructed by the Union Pacific Railroad for their road from Omaha to Fort Bridger, we shall find that at Omaha, the initial point, the altitude is 968 feet above tide level. At the mouth of Lodge Pole creek, a distance of 377 miles, we have an elevation of 3528 or a gradual rise in that distance of 2560' or a grade of about 7 feet to the mile. From the mouth of Pole creek to Crow creek crossing near Cheyenne 513.76 miles west of Omaha we have reached an elevation of 6019 feet, or an average grade of over 9 feet to the mile for the entire distance.

At Evans' Pass on the summit of the Laramie range, we have reached the highest point in the Rocky Mountains, 8248', a distance of 545.62 miles west of Omaha. The average grade is over 13 feet to the mile. But for 100 miles west of Omaha the average grade of ascent increases as we approach the mountains.

If we take the distance from Crow Creek Crossing at the foot of the mountains to Evans' Pass, "the Summit," a distance of 31.86 miles, we have an average grade of ascent of nearly 70 feet to the mile. We can see clearly by these figures the plan of growth of that portion of our continent west of the Mississippi. A number of these profiles have been constructed across the continent from the Mississippi to the Pacific ocean, from the north line to the south, all pointing to the same result, and all agreeing substantially in the aggregate results.

Passing over this first range of mountains to the Laramie plains, from Crow Creek Crossing to Laramie river 57.53 miles, and 571.39 miles west of Omaha, the elevation is 7175 feet above tide water. Showing that even in the plain country on the west side of the first range the elevation is over 1000 feet higher than at the base of the mountains on the east side.

From the latter point westward there is a continued line of ascent and descent produced by the same forces that elevated the whole Rocky Mountain Chain. Passing the Humbolt mountains we then descend by a moderate grade to the Pacific ocean. The intermediate portions are occupied by a continued series of more or less elevated mountain ranges with intervening valleys which are always at a considerable height above the sea, but vary at different points from east to west. For example the elevation of the Laramie plains near Fort Sanders is 7175 feet, at Salt Lake Valley 4285, making a difference of 2990 feet. We shall endeavor to show hereafter that this difference in the elevation of the two localities of nearly 3000 feet operates most favorably upon the agricultural resources of Salt Lake Valley. While the summers in the Laramie plains are very brief, and it will always be difficult under the most favor-

able circumstances to produce crops to any extent, the productions of Salt Lake Valley are among the finest in the world.

We can see at a glance therefore that the whole country west of the Mississippi is as it were an elevated Plateau, out of which rise, as if by the bursting of the crust, a vast series of ranges of mountains, trending in the aggregate nearly north-west and south-east, and each of the series made up of an infinite number of minor ranges trending in almost every possible direction. In many instances important ranges of mountains are separated from the main chain by extended plains composed of cretaceous or tertiary formations, and without a knowledge of the geological structure of the country, they would seem to be entirely disconnected.

The Black Hills of Dakota, occupy an area of 6000 square miles. If we examine the map this important range seems to be entirely isolated from the main range, but from the south-western side extends a low anticlinal valley, just exposing the tertiary and for a portion of the distance the cretaceous beds, and linking the Black Hills with the Laramie range near Fort Laramie.

Again, the same may be said of the Big Horn range, from the south-east end of which along the valley of Poison Spring creek extends an anticlinal valley, joining the Big Horn range with the Laramie near the Red Buttes. All these isolated ranges, however distant they may appear to be from the main range, or however small they may be, are really connected to the eye of the geologist. It is thus that the anatomy of this great mountain system can be worked out in detail. Never can it be well done, so as to command the unqualified approbation of the scientific world, until the minutest topography and the geology are united together.

The northern portion of the Laramie range properly commences near the Red Buttes. Here the nucleus of feldspathic granite or syenite is concealed by the overlying unchanged beds, and a broad interval occurs which is occupied by a great variety of formations, ranging from the carboniferous to the most recent tertiary. In its southward extension this range seems to flex around from an almost easterly trend to a south-west direction, forming almost a half circle. It then joins on to the main range in the neighborhood of Long's Peak. Thus the Laramie range constitutes the east side and the greater part of the north side of the Laramie plains which forms, thus enclosed, a huge park. On the south side is the Medicine Bow range, the loftiest ridges covered with perpetual snow. Connected with this range also are numerous minor ranges. The west side is an open rugged barren sage plain, with here and there detached small mountains extending far westward toward Salt Lake valley.

The Laramie range forms the most beautiful illustration of an anticlinal ridge I have ever met with in the Rocky Mountains, with the exception of the Black Hills of Dakota. Either one of these ranges if thoroughly studied, would form excellent monographs of the physical geography and geology of the mountain region.

The nucleus of the Black Hills is composed of red feldspathic granite

and other metamorphic rocks, and inclining from the flanks may be seen the upturned edges of the Potsdam sandstone, Carboniferous limestones, brick red sands and sandstones. Triassic, Jurassic marls, Cretaceous and Tertiary rocks, all dipping at various angles, but in such a way as to be easily accessible to the student.

The Laramie range is equally systematic in its plan of development but rather more complicated, and the results of erosive action are much more strongly shown and the superficial deposits or drift in many places conceal the underlying rocks. Like the Black Hills the Laramie range does not give rise to any important streams of water. Myriads of little streams originate in or near the dividing ridge and cut their channels down the slopes and flow into the North or South forks of the Platte.

The main branch of the North Platte rises in the range of mountain which forms the north side of the Middle Park, very near Long's Peak. It takes a course a little west of north, flows through the middle of the north park, cutting its way through immense canons between the North Park and the Laramie plains. It then continues nearly a north course through tertiary as well as cretaceous rocks to its junction with the Sweet Water, when it bends around to the eastward so that near the Red Buttes its course is nearly south-east until it reaches the main Platte near Long. 101°.

The Sweet Water, which is the principal branch of the North Platte, rises in the southern end of the Wind river mountains, and flows nearly east and unites with the North Platte near Independence. These streams flow through nearly every variety of geological formations which occur in the West. From the junction of the Sweet Water to Red Buttes, it flows through granite, carboniferous limestone, red beds, jurassic marls, and White river tertiary beds. From the Red Buttes, through lignite-tertiary to a point about 100 miles north-west of Fort Laramie. There the White river tertiary beds overlap the lignite-tertiary, and then continue to the forks of the Platte.

The Medicine Bow and the two Laramies are important branches of the North Platte, and take their rise in the lofty snow capped mountains on the south side of the Laramie plains. The region north of the North Platte is mostly a vast sage plain and but few small branches flow in from that direction, but a multitude of small streams cut deep channels through the sides of the Laramie range and flow into the North Platte.

From Red Buttes to Fort Laramie, a distance of 150 miles, many beautiful little streams rise in the Laramie and pour a good volume of water into the Platte. These creeks occur every few miles, and in their passage from the mountain they have not only worn a deep channel in the steep side of the mountain, sometimes 1000 feet or more in depth, but they have also scooped out a wide deep valley which affords the best of pasture, ground for stock in summer and warm sheltered places in winter.

The main branch of the South Platte rises in the range of moun-

tains which bounds the west side of the south park, and flows about north-east to Cache la Poudre, and there bends round slightly toward the east and joins the main Platte. The little branches that flow from the mountain sides are very numerous, and each one cuts a tremendous channel through the sides of the mountain, affording most excellent sections of the strata for the geologist. Nearly all the branches that rise in the plains have very wide valleys, but are mostly dry, especially in the latter part of the summer and autumn. Although the Platte river is never navigable at any season of the year, yet the area drained by it is immense, at least 800 miles from east to west and 350 from north to south, or an area of nearly 300,000 square miles; and yet the North Platte is one of the minor branches of the Missouri river.

The South Platte flows through the different formations along the flanks of the mountain; and in its course through the plains cuts the lignite-tertiary for 50 miles or more, when the White river tertiary overlaps the plains to the junction.

The above brief remarks are intended principally to show by the geography the gigantic scale upon which every thing in this Western Country is planned, that even the district drained by the Platte and its branches is larger than all New England, New York and Pennsylvania.

September 1st, I left Fort Sanders with my party to examine the country along the southern border of the Laramie plains. We passed over the different beds of the cretaceous period for about 30 miles, until we reached a point near Cooper's creek, when indications of the tertiary begin to overlap the cretaceous.

The examples of the erosive action of water along the northern side of the mountains that border the Laramie plains are numerous. In the valley of Cooper's creek near the foot of the mountains there is a triangular space about five miles long, and two or three miles wide on the south-west side. On the south side there is a hill 500 feet high, the summit of which is composed of drift, and the surface paved with partially worn rocks. On the north-west side there is a long ridge, the top of which is composed of the yellowish sandstones of cretaceous formation No. 5, in which a few characteristic species of fossils, like *Inoceramus*, occur. These ridges seem to converge about two miles below the Stage Station, so that the creek passes through a sort of gorge. The valley of the creek is covered quite extensively with drift materials derived from the neighboring mountains.

Six miles west of Cooper's creek we find the first good exposure of coal. The upper cretaceous beds crop out occasionally in that vicinity, but are overlapped by the coal bearing strata.

The slopes are all so gentle and the superficial drift covers the country to such an extent that I found it difficult to get a good section. No. 5 (cretaceous) seems to pass gradually up into the coal-bearing beds, and the change in the sediments of the two systems is slight.

What appears to be the lowest bed of the coal-bearing series in this region, is a brown grit, very loosely aggregated with, sometimes, irregu-

lar layers of sandstones ; at other times inclosing concretions, with concentric layers or composed of thin laminæ and readily cleaving in pieces on exposure to the atmosphere. Immediately underneath the coal lies a bed of drab clay varying in thickness from three to five feet. The first locality where the coal is exposed by the uplifting of the beds is near a small lake. The dip is about  $10^{\circ}$  towards the north-east and from the mountains. There is about six to eight feet of pure and impure coal together. Above, is a bed of drab clay ; and over this again a layer of fine grit, capped with hard sandstone. The clay over the coal is full of small rounded nodules of iron and yellow sandy concretions.

About a mile west from this locality is another outcropping of coal. The bed is here separated by about  $2\frac{1}{2}$  feet of drab arenaceous clay, with five feet of excellent coal above and six to eight feet below, making in all from ten to twelve feet of solid coal. Some of it has a dull bituminous look, other portions are as glistening and black as anthracite. Above the coal is the usual clay bed, many layers in which are largely composed of the stems and leaves of plants. Above this there are beds of loose rusty brown sand and sandstone with some ferruginous concretions ; and a layer of light brown very compact silicious rock caps the hill. The dip of the beds is not more than  $3^{\circ}$  to  $5^{\circ}$ . At the immediate entrance to the mine the inclination is about  $5^{\circ}$ . The coal can be easily wrought and the mine well drained, in spite of its clay roof. The coal is of excellent quality, but like most of the brown coals of the west, crumbles on exposure to the atmosphere, as appears from the condition already of the large coal heaps in front of the mine.

So far as I have been able to ascertain, I am inclined to believe that the coal bed already alluded to is the lowest in the region and identical with the one so successfully worked at Carbon Station on the line of the Union Pacific Railroad ; but I do not think that it is the oldest coal bed in the tertiary series of the West.

The valley of Rock creek is from three to five miles in width and evidently a valley of erosion. On the west side of it there is a ridge at least 500 feet high, composed of tertiary beds, which in some places incline  $10^{\circ}$  to  $15^{\circ}$ , but the general dip is not more than  $5^{\circ}$ .

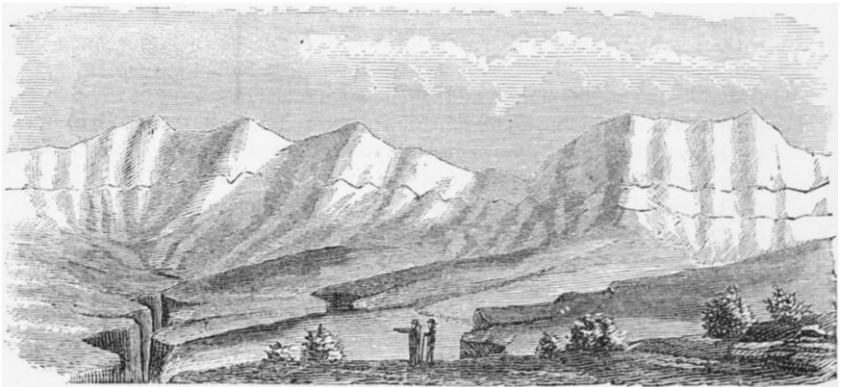
On both sides of the stage road for ten miles west of Rock creek there is a large area covered with huge piles of rusty brown sandstone, mostly concretionary. In some localities a great many impressions of deciduous leaves were found. The tertiary beds extend to the mountains and form a large part of the foot hills. Here lofty wall-like exposures of sandstone make their appearance, giving a very rugged appearance to the country. As far as the eye could reach we saw peculiar looking pyramidal, conical and dome-shaped hills, from 300 to 500 feet high, composed of alternate layers of rusty yellow sandstone and greenish gray indurated sands, which are sometimes in the valleys of streams exposed for a thickness of 1000 or 1500 feet. These beds incline gently from the mountains, about north-east.

Since crossing the Big Laramie river exposures of the red beds have not

been observed in the foot hills of the mountains. Usually they form a most conspicuous feature in the scenery. Their absence here is due either to the comparatively small erosive action, insufficient to wear away the cretaceous and tertiary beds; or to the fact that they are covered with a thick deposit of drift. The inclination of the beds are gentle and the ascent of the mountain side is as it were by steps; one series of foot hills rising slowly above another, until the snow capped ranges are reached. In this region all the hills, and even the gorges through which the little streams flow, are so covered with debris and the whole surface is so clothed with grass, that the rough points are smoothed down and the underlying rocks are difficult to see. Even Elk mountain, which must rise at least 1500 feet above the bed of Medicine Bow creek, is so smooth and so covered with grass, that the rocks are nowhere visible.

North of the road for 30 miles or more, the tertiary beds are on the contrary worn by atmospheric agencies into a great variety of rugged forms, so that the scenery recalls portions of the "Bad Lands" on the Upper Missouri composed of the same formations. Fig. 1 illustrates the character of the coal-bearing formation of the Upper Missouri, but is equally descriptive of the region under notice. The feature of greatest interest is that which affords evidence of comparatively recent glacial action, not merely in valleys of erosion, but in vast deposits of water-rolled rocks, everywhere visible. The mountain sides toward the plains are literally paved with rounded boulders, commonly of no great size; but the sides of the hills opposite the mountains, have scarcely any on them, and are in most cases covered with bushes or with grass. The bottoms of the streams are also covered with pebbles or boulders; and the nearer the mountains the larger and more numerous these rocks become.

FIG. 1.



The Medicine Bow creek, a fine mountain stream fringed with a considerable belt of cotton-wood, has a valley extending far into the mountains, with a gradual ascent. It is by far the most beautiful valley west

of the Laramie river. Although covered thickly with boulders the soil is good, and the grass excellent. It has been for years a favorite pasture ground.

Elk mountain is a short range of spurs with its highest point fronting the creek; it resembles the short range, with abrupt front, east of the Little Laramie. The metamorphic rocks have been uplifted, while the unchanged rocks have remained quiet, or been let down at the foot of the mountain, without leaving that series of upheaved ridges which we find running along the base of most of the mountains. The range is about 10 miles long, forming what I have called an abrupt anticlinal; that is, on one side of the mountain the anticlinal is complete, the unchanged rocks inclining *from* the mountain in regular order of sequence; while on the mountain side the rocks are nearly vertical, and the sedimentary beds jut up against the base, their edges being entirely concealed. Against the north side of Elk mountain the cretaceous and some of the tertiary beds jut so abruptly that all the older rocks are concealed, while on the opposite side, the entire series, from the granite nucleus to the cretaceous formation, may be measured across their upturned edges.

Along the immediate base of the mountains there is a belt of country which in many instances might be called a monoclinical valley. It has been even more smoothed by erosion than any of the valleys of the streams, and always runs at right angles to them. Through this valley of erosion the old stage road and Western Union Telegraph line is located.

North of the road can be seen a series of upheaved ridges somewhat irregular in their continuity but gradually receding northward like sea waves. The first ridge is composed of a series of dark brown indurated clays and sands, with layers of more or less laminated rusty sandstone of fine texture, and tendency to concretionary forms, varying rapidly in thickness from 2 to 10 or 12 feet, dipping N. 20° W. from 5° to 10°, 20° west of north. In this ridge are quite extensive beds of lignite, one of which is about six feet thick separated into three parts by layers of clay. In the harder layers above and below are great quantities of indistinct vegetable impressions. The interval between the first main ridge and the second is about 1½ miles, and in that interval several lignite beds crop out with layers of light gray fine grained siliceous rock.

The second main ridge is composed of a variety of beds inclining 3° to 5°, the general color being brown, or light drab, while the harder layers are rusty sandstones. One bed, perhaps 50 feet thick, is of fine gray indurated sand with a greenish tinge. At the summit of this ridge were very distinct indications of the lignite bed at some period in the past. Several feet of rocks were baked to a brick red color, and fragments of completely fused rock lay scattered about. From the bed of the Medicine Bow to the summit of the second ridge I estimated that 1200 to 1500 feet of strata were exposed to view, and from the presence of lignite and deciduous leaves I regarded them all as belonging to the tertiary series. Some of the sandstones are made up of an aggregate of crystals of

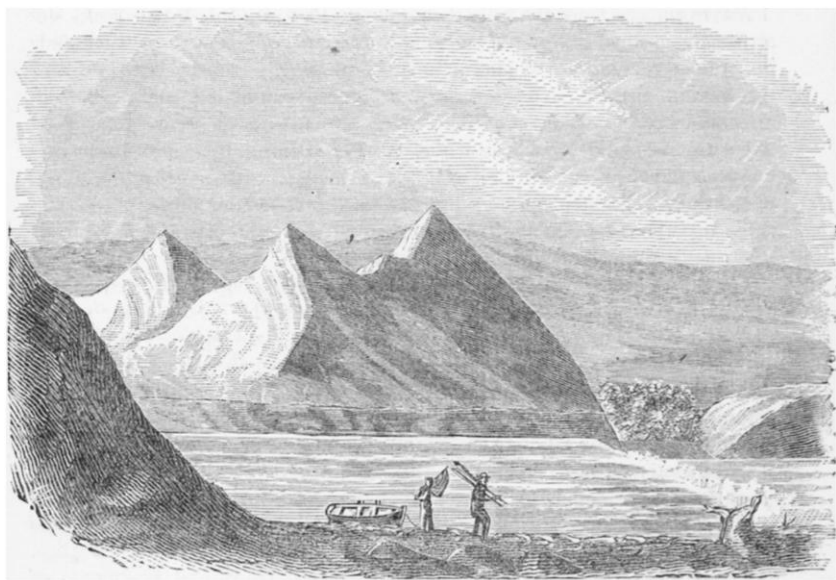
quartz and feldspar, showing that the materials were derived at least in part from the metamorphic rocks. Many of these sandstones disintegrate by exfoliation, or exquamation, and have the rusty spherical concretions scattered through them.

The main trend of these ridges is N. E. and S. W. The general appearance of the country is extremely desolate and cheerless; scarcely any vegetation but sage and grease-wood; with here and there a little lake, which from its alkaline character only adds to the dreariness of the scene.

Near the summit of the second ridge in the burnt rocks are quite abundant impressions of plants; and more especially lower down, about the middle of the ridges, there is a layer of the iron rocks about 2 feet in thickness largely composed of fragments of leaves.

A few miles west of Fort Halleck a very conspicuous hill, called Sheep mountain, is composed of carboniferous limestones, red beds; and is probably capped with lower cretaceous rocks. These beds incline  $25^{\circ}$ , but a very hard bed of sandstone capping the summit dips  $35^{\circ}$ . There appears to be an unusual thickness of triassic (?) rocks at this locality. The average dip of the strata is from  $30^{\circ}$  to  $50^{\circ}$ , varying between west and north.

FIG. 2.



From Medicine Bow river to Rattle Snake Pass, a distance of about 30 miles, the road extends through a monoclinal valley.\* For nearly our

\* Fig. 2 illustrates the character of the upheaved ridges which everywhere are seen upon the margins of the mountain ranges, extending in many cases for miles, like waves; and the geologist can walk across the upturned edges of all the formations from the granite to the most recent tertiary inclusive.

entire route the road seems to form the line of separation between the cretaceous and tertiary rocks, the former being well displayed on our left, jutting up against the mountain sides; the latter extending in wave like ridges into the distance on our right. As we approach Pass creek however about 5 miles to the east, the cretaceous beds reveal themselves clearly on the right side of the road, No. 5 attaining a great thickness; while, on the left, inclining from Sheep mountain Numbers 3 and 2 are very plainly shown in a series of irregular and rather low ridges. All along Elk mountain the red beds are visible but not conspicuous, and they do not give color to the debris at the foot of the hills. In this vicinity the tertiary beds must be at least 5000 feet thick, which, with an equal thickness of the cretaceous, makes in all at least 18,000 feet, a larger development than I know at any other point to the eastward. Indeed we shall be able to show that these formations continue to increase in thickness as we go west.

On the north side of Pass creek we have an uplift of rather fine grain yellow sandstone, which presents a front like a wall composed generally of vertical columns. On the summit are isolated piles of every form, the relics of erosion. The sandstone is about 200 feet in thickness and the ridge inclines northward at an angle of about  $19^{\circ}$ . The trend of all these ridges varies between north and west.

As we emerge from the hills through the Pass on the Pass creek, we strike a vast open plain, and the ridges of upheaval seem to pass off and die out en echelon in the plain, the ends making a gentle flexure from the west northward, so as to form one side or rim of the plain. There appears to be in these formations many alternate beds of brownish yellow sand and sandstones, the whole readily yielding to atmospheric influences, covering the hills as well as the valleys, with a great depth of fine sand, from which the long lines of harder sandstone project. These ridges of upheaval run at various distances from each other, from 100 to 1000 yards, with monoclinical valleys intervening.

The broad plain west of Elk mountain must be a region of depression; or a portion of the country left undisturbed while the surrounding parts were elevated. As far as the eye can reach this plain appears to be perfectly level; and no cuts to show the character of the underlying beds. A thick deposit of drift covers every thing. On its northern side the mountain ridges seem to trend about north-east and south-west, the southern end sloping gently down with the plain. The rusty calcareous sandstones which form the inner ridges facing the plain are undoubtedly cretaceous and incline  $30^{\circ}$  to  $45^{\circ}$ . These rusty sandstones here form a belt about  $1\frac{1}{2}$  miles in width, with intercalated layers of yellow arenaceous material covered with grass, only the harder layers projecting here and there above the surface. In one of these higher ridges of sandstone a Baculite (*B. ovatus*) was found. In another ridge was a seam about six inches in thickness composed entirely of a small oyster about the size, "though probably distinct from" *O. Congesta*. In the plain country,

even far distant from the mountains, the rocks are more or less disturbed, but generally not exposing older beds than the cretaceous.

We find also that there is an irregular series of anticlinals and synclinals resembling somewhat, but on a gigantic scale, the furrows in a ploughed field. Not unfrequently we meet with a high synclinal ridge, formed of rocks inclining toward each other; and then following the same beds along and across the ridges we shall find them dipping away from each other making a synclinal valley.

I have given my observations along this route somewhat in detail from the fact that no accurate information concerning the geology of this region has ever been published; and because we have had no definite data for coloring a geological map. Our course was along the Overland Stage Road just at the base of the mountains, on the south side of the Laramie plains, from 5 to 20 miles south of the Union Pacific Railroad line; and by comparing my observations of the geology along the stage road with those along the line of the railroad it will be seen that there are many points of difference. As I have before remarked, the Laramie range of mountains forms one of the most complete and beautiful anticlinal systems in the West.

The Laramie plains, as the area enclosed by these mountains is called, exhibits a broad, undulating almost treeless, surface about 60 miles long from East to West, and 50 miles broad from North to South. From Fort Sanders along the stage route to Little Laramie river, the distance is about 18 miles. The surface is quite undulating, but all the slopes are moderate in their inclination. All the basis rocks belong to the cretaceous period. At the crossing of the Big Laramie may be seen a small thickness of the black clays of No. 2, and here and there are isolated hills which show the yellow chalky layers of No. 3. Some of the higher ridges which extend down into the plains from the foot of the mountains reveal here and there the rusty yellowish arenaceous marls of No. 5.

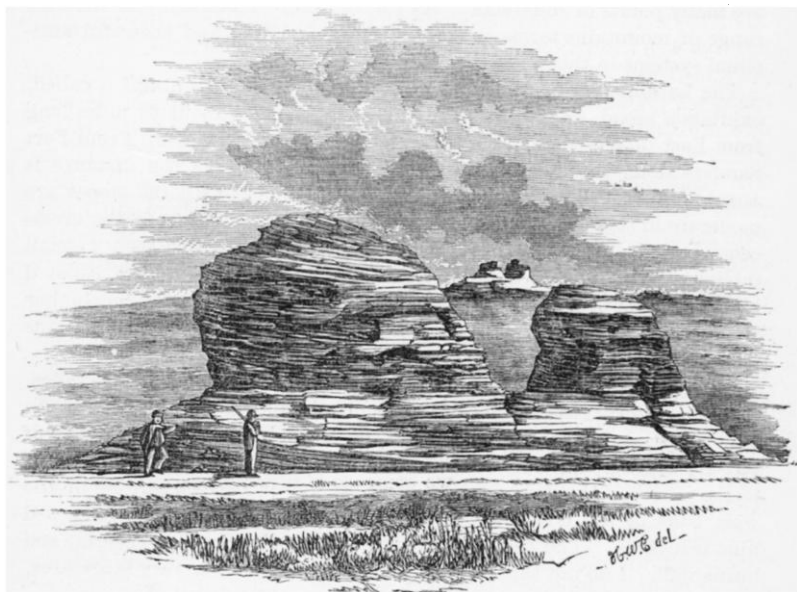
From Little Laramie Station to Cooper's creek the distance is 15 miles. Over this interval the cretaceous rocks prevail and belong mostly to the upper portion of that period. There are probably isolated patches of tertiary overlapping the cretaceous beds. One of these isolated areas of tertiary occurs about two miles north of Cooper's Creek Station on the west bank of the creek where an excellent coal bed has been opened nine feet thick. The coal is quite pure, compact, but rather light, and burns well. I do not think it will be continuous over a very large area, but it will yield a large amount of fuel before it is exhausted.

From this point westward nearly to Fort Bridger, and perhaps beyond, the tertiary beds may be said to prevail in the plain country. Rocks of older date with comparatively few exceptions are not seen except in close proximity to the mountains. In some instances the mountains abut abruptly on the plains, the tertiary or cretaceous beds jutting against the granite or igneous nucleus, and concealing for long distances all the older rocks. Again, intervening between the plain country and the principal mountain ranges are 50 to 100 miles of what may be called

foot hills, or minor ranges of the mountains, in which are exhibited on a grand scale the entire series of unchanged rocks known to exist in this country.

In the mountains near the sources of the Little Laramie the red beds show themselves in very great thickness and give to the scenery peculiarly picturesque features.\* Near Elk mountain the red beds appear again; but in the interval they seem to be partially concealed either by drift or cretaceous and tertiary beds. It will be impossible to represent minute details of the geology of this country by colors except on a carefully prepared topographical map constructed on a much larger scale than any that we have. We are satisfied, however, whether the older formations are well shown or are concealed entirely, or in part, that they either do now or did once extend across the country with a nearly uniform thickness.

FIG. 3.



We will now return to Laramie City and examine the geological character of the country along the line of the Union Pacific Railroad westward. From Laramie City to Cooper's Lake Station, a distance of 25.6 miles, there is a good degree of uniformity in the character of the coun-

\* The action of the atmosphere upon these brick red sandstones of the Triassic Age is beautifully shown in the wood cut, Fig. 3, taken from a photograph. These worn sandstones form a conspicuous feature in the scenery of the Laramie Plains.

try. On our right the Laramie range appears like a wall bending round to the north-west and west, and finally disappearing from view at Cooper's Creek Station. Near the crossing of the Big Laramie river we see on our right the red beds which are somewhat marked. We can follow them up to the foot of the mountains by their peculiar brick red color. Then come the cretaceous rocks, especially the upper members of the group, soon after crossing the Laramie river, and continue to a point about 5 miles east of Como Station, more than 60 miles west of Laramie City. There may be some few isolated patches of the tertiary beds. The principal rocks seem to belong to No. 5.

Carmichael's Cut east of Rock Creek is a locality quite well known. The strata cut through are mostly rather friable fine grained rusty gray sandstones, with bluish brown calcareous concretions of various sizes scattered through them, which when broken open reveal a great variety of shells—Baculites, Ammonites, Inoceramus, and many other species characteristic of No. 4 and 5, which undoubtedly blend throughout this region, and cannot be separated as distinct divisions of the system. No. 3 has not been observed along the immediate line of the railroad, but it is well showed in many localities in the Laramie plains.

From Laramie City to Cooper's Station the country as far as the eye can reach presents a cheerful appearance. The irregularities of the surface are smoothed down and a long stretch of level prairie is covered with grass, with here and there a grass covered ridge or rounded butte. The basis rocks are mostly indurated arenaceous clays or loose yellow sands which yield readily to atmospheric influences. There are many rounded arenaceous concretions, and sometimes a thin layer of laminated sandstone. There is a slight disturbance of the beds; and the ridges of upheaval seem to trend nearly east and west.

As we proceed westward from Cooper's Station we find the black clays of No. 2, and the appearance of the country becomes dreary and sterile in the extreme. They extend to a point about 5 miles east of Como. The waters are alkaline, and there is no timber along the creeks except stunted willows, and very little grass or vegetation of any kind; as far as the eye can reach nothing but black plastic clays.

Just before reaching Como we come to a very interesting quarry of sandstone from which the materials for the construction of the extensive railroad buildings at Laramie City and Cheyenne are obtained. The rock is a gray, rather friable, sandstone, and occurs in isolated patches resting on the shaly clays of No. 2, and are so filled with fragments of vegetable impressions, sometimes quite distinct deciduous leaves, that one is reminded of the tertiary sandstones. I am inclined to think however that it is a local deposition of sandstone in the cretaceous series. This point and the district about Como is extremely interesting to the geologist, and there are some curious problems yet to be solved.

At Como Station the railroad runs for some distance through a distinct anticlinal valley, the strata inclining away to each side. The south side of the road exhibits the most complete series of the beds. A high ridge

is composed of jurassic beds mostly capped with the sandstones of No. 1, while as far as the eye can extend southward the low wave like ridges of No. 2 can be seen. Towards the southwest the anticlinal valley seems to close up, but north-eastward expands indefinitely, and extends no doubt to the Laramie mountains. In the valley the red arenaceous beds are quite conspicuous.

These jurassic rocks are composed for the most part of alternate layers of loose sands and some harder beds of sandstones, but there are a few layers of sandstone and marl; and in these are great quantities of an *Ostrea*, *Pentacrinus*, *Asteriscus*, and *Belemnites densus*, all well known jurassic types.

These beds throughout the jurassic series are full of tidal ripples, mud markings and irregular laminae of deposition, indications of a shallow water deposit. All the fossils are badly broken and worn as if they had been transported from a great distance and deposited in turbulent waters. About a mile west of the station the road cuts through the full series of jurassic beds with Nos. 1 and 2 of the cretaceous inclining north-west at an angle of 45° to 50°.

From a point about 10 miles east of Como to St. Mary's Station, for a distance of about 50 miles, the tertiary formation occupies the country with the sands, sandstones and clays peculiar to it and also numerous coal beds. The most marked development of the coal beds is at Carbon Station, about 80 miles west of Laramie Station. The rocks incline nearly south-east or south and east. Three entrances have been made to mine a bed 9 feet thick. The openings follow the dip and consequently descend. The mines are about 300 yards from the railroad; a side track has been laid to them. More than 1000 tons of coal have already been taken out, and the Union Pacific Railroad Company are ready to contract for any amount that can be supplied. The coal at Carbon is of the best quality of tertiary splint, very compact and pure. It is not as hard as anthracite, but the miners informed me that it was more difficult to work than the bituminous coals of Pennsylvania. It is used to a great extent on the locomotives, and the engineers speak in high terms of it. Over the coal is what the miners call slate, a somewhat earthy bed breaking into slabs showing woody fibre, and much of it looking like charred wood or soft charcoal. As we pass up in the section fragments of deciduous leaves are seen more distinctly, and finally the whole graduates into a dark drab clay. At the bottom of the coal are thousands of impressions of deciduous leaves, such as *Populus*, *Platanus*, *Tilea*, &c. Some of the layers of rock, 2 to 4 inches in thickness, are wholly composed of these leaves, in a good state of preservation, and so perfect that they could not have been transported any great distance.

The Union Pacific Railroad Company have placed their coal interests in charge of Mr. Thomas Wardell, an old English miner, who is constantly employed in prospecting and opening mines the whole length of the road. At Carbon he has erected six pretty cottages, as residences for the miners, and a number more are in process of building. At

Separation and Point of Rocks other villages will be built. All the apparatus for permanent and extended mining operations are being gradually introduced. Nearly all the wood now along the line of the road has to be transported from 10 to 40 miles, and in two years from the present time most of it within a reasonable distance of the road will have been consumed. The future success of this great thoroughfare is therefore wholly dependent on the supply of mineral fuel, and its importance cannot be too highly estimated.\*

From St. Mary's to Rawlings Springs, a distance of about 30 miles, the railroad passes over rocks of cretaceous age. No coal beds need be sought for in the immediate vicinity of the road, although it is quite possible that on the north side of the road isolated patches of tertiary containing coal may be found. The railroad from a point about 8 miles east of Benton to Rawlings Springs, passes through one of the most beautiful anticlinal valleys I have seen in the West. On either side the rusty gray sands and sandstones dip away from the road at an angle of 10° to 15°. This anticlinal valley is most marked near Fort Steele at the crossing of the North Platte.

About 5 miles east of Fort Steele I made a careful examination of a railroad cut through a ridge of upheaval which inclined about south or a little east of south. We have, exposed here, commencing at the bottom :

1. Gray fine grained sandstone, rather massive and good for building purposes and easily worked, 80 feet thick—dip 25°.
2. A seam, 2 feet thick, of irregular black indurated slaty clay, with layers of gypsum all through it then 2 feet of arenaceous clay.
3. Ten feet of rusty gray compact sandstone.
4. Eight feet of clay and hard arenaceous layers, very dark in color, passing up into harder layers which split into thin laminæ, the surfaces of which are covered with bits of vegetable matter.
5. About 50 feet of rusty yellowish gray sandstone. All these sandstones contain bits of vegetable matter scattered through them.
6. 100 to 150 feet of steel-brown indurated clay with some iron concretions. The clay is mostly nodular in form.
7. A dark brown arenaceous mud rock, quite hard, 30 feet.

From bed 5 I obtained numerous species of marine shells, among them a species of *Ostrea* and *Inoceramus* in great numbers. The upper surfaces of the hard clay layers appeared as though crowded with impressions of sea-weeds or mud markings. In another railroad cutting about 4 miles

\* Mr. J. P. Carcou, an assistant on the survey, made an analysis of a fair specimen of the coal from the Carbon mines with the following result:

Moisture at 100° C.	11.60.
Volatile Combustible Matter,	27.68.
Fixed Carbon,	51.67.
Ash,	6.17.
Sulphur,	2.88.
Color of Ash, light grey.	
Specific gravity, 1.37.	
Weight, per cubic yard, 2212 lbs.	

east of Rawlings Springs I obtained the same *Inoceramus* and a large species of *Ammonite*. These fossils are important in establishing the age of these rocks.

At Rawlings' Springs are some very interesting geological features. At this locality the elevatory forces were exerted more powerfully than at any other point along the railroad from Laramie Station to Green river. The entire series of rocks are exposed here, from the syenites to the cretaceous inclusive. The railroad passes through an anticlinal opening. To the south of the road are variegated gray, brown and reddish siliceous rocks dipping  $5^{\circ}$  to  $10^{\circ}$  S. W. A very hard bluish limestone resting upon them I have no doubt is carboniferous, although I was unable to find any fossils in this region. North of the road ridges of upheaval stretch away toward the north-west and attain a height of 1200 to 1500 feet above the road. On careful examination the red syenite may be found exposed in a number of places, and gives us the opportunity of studying the relation which the unchanged rocks sustain to the metamorphic. The syenite beds dip  $70^{\circ}$  about S. E., the unchanged beds resting upon them in nearly a horizontal position. The layers immediately on the syenite are a beautiful pudding stone of rounded quartz pebbles and feldspar, and above it layers of fine siliceous rock with thin intercalations of clay, the whole having the position and appearance of Potsdam sandstone. I am inclined to believe that we have here lower silurian representatives. In all cases these rocks repose on the upturned edges of the syenite; sometimes nearly horizontal; again inclining  $3^{\circ}$  to  $10^{\circ}$ . In one or two places these lower silurian (?) beds are lifted a thousand feet or more into the air, still maintaining a nearly horizontal posture. On the mountain sides the beds are broken off so as to incline  $50^{\circ}$ ,  $60^{\circ}$ , up to nearly  $90^{\circ}$ .

These siliceous rocks, covered with ripple marks, &c., afford excellent building stone, and are much used by the railroad company. They reach a thickness of 500 to 800 feet. Upon them rests the blue limestone, 30 to 40 feet thick; then variegated sandstones; and the red beds in the distance.

From the tops of these ridges one can see numbers of both synclinal and monoclinal valleys. There is one monoclinal valley, 3 to 5 miles wide, which stretches far into the north-west, a smooth and level grassy prairie. All these ridges have suffered great erosion, and the silurian (?) beds are planed and grooved even to a greater extent than the more recent beds. Everywhere the evidences of erosion during the drift period are on a gigantic scale.

A fine sulphur spring from under the bed of blue limestone gives name to the station. The water is clear and possesses excellent medicinal properties.

About 4 miles west of Rawlings' Springs the tertiary beds begin to overlap, but in the distance on either side are lofty ridges of cretaceous and perhaps still older rocks. The ridge, 15 miles south of Separation, at least 1000 feet high, is certainly formed of lower cretaceous and prob-

ably also of that great thickness of sandstones and clays which hold a position between the transition No. 1, and the brick red beds.

Near Separation, about 10 miles west of Rawlings' Springs, a coal bed 11 feet thick has been opened, probably the same as the one opened at Carbon, and near Rock and Cooper creek. The dip is nearly west about 10°. The opening being at the summit of the hill, all the coal will have to be drawn up a slope, and the difficulties of drainage will be greatly increased. The coal is of excellent quality. Above and below the coal is the usual drab indurated clay. Below the clay is a bed of gray ferruginous sandstone.

On the summits of the hills in the vicinity are layers of fine grained siliceous rocks with arenaceous concretions, some of them containing impressions of deciduous leaves.

The tertiary beds lie in ridges running across the country. The beds are uplifted in every direction. A more desolate region I have not seen in the West. Nothing seems to grow but sage bushes, and in some of the valleys they grow very large. All over the surface of the hills and in the plains are great quantities of water-worn pebbles. Many of these valleys were scooped out by an amount of waters far in excess of any known at the present day in this region. Some of the widest and deepest do not now contain any running stream.

The layers of fine grained sandstone on the hills in this vicinity contain more or less impressions of leaves, like *Populus* and *Platanus*, in a good state of preservation.

West of Separation the dip of the tertiary beds diminishes. Before reaching Creston, about 13 miles west of Separation, they lie nearly horizontal, and all the surrounding country presents more the appearance of a plain. At that station the Union Pacific Railroad Company have a well 100 feet or more deep, at a depth of 83 feet in which was struck an 8 foot coal bed, with 4 feet of excellent coal and 4 feet of coaly shale. The coal was of about the same quality as that near Separation, probably from the same bed. If so, coal at a depth of about 80 feet must underlie an area of at least 100 square miles. In this well beds of bluish arenaceous clay were passed through first, then black clay with carbonaceous matter throughout. Just over the coal was fine bluish indurated clay with very distinct impressions of leaves, among which the most abundant were *Populus* and *Platanus*. The railroad cuts and the valleys themselves show very distinctly the character of the intermediate softer beds. The erosion has been so great in this country, and all hills and cañons are so covered with debris that it is almost impossible to obtain a clear idea of the color and composition of the intermediate softer beds. The harder sandstones, &c., project from the surface and are accessible to the eye without much excavation. Marine and fresh-water tertiary formations occupy the whole country along the line of the railroad to Quaking Asp Summit, west of Fort Bridger, and possibly over to Salt lake to a greater or less extent.

From Creston to Bitter Creek Station, a distance of 45 miles, the beds

are mostly fresh water and hold a nearly horizontal position. West of Bitter creek we get again upon marine tertiaries dipping  $3^{\circ}$  to  $6^{\circ}$  nearly east. We have therefore between Rawling's Springs and Green river a sort of synclinal basin, the marine tertiary dipping west about  $10^{\circ}$  on the east side, and the same marine beds inclining east  $3^{\circ}$  to  $6^{\circ}$  on the west side; while at Table Rock, Red Desert, and Washakie, a considerable thickness of purely fresh water beds are filled with shells of the genera *Paludina*, *Unio*, *Melania*, &c.

Table rock is a square butte lifting itself about 400 feet above the level of the road, composed of the beds of a sandstone which in many instances is little more than an aggregation of fresh water shells.

After leaving Bitter Creek Station the hills approach nearer to the road and show the characteristic features of the marine tertiary again. Seams of coal appear in many places, while yellow arenaceous marls, light gray sand with indurated clay beds and more or less thick layers of sandstone occur. The dip varies from  $3^{\circ}$  to  $6^{\circ}$  east or nearly east.

At Black Butte Station on Bitter creek, about 15 miles west of Bitter Creek Station there is a heavy bed of yellow ferruginous sandstone, irregular in its thickness and in part concretionary, and full of rusty concretions of sandstones of every size from an inch to several feet in diameter, mostly spherical, and when broken revealing large cavities filled with oxide of iron loam. This sandstone, 150 to 200 feet in thickness, forms nearly vertical bluffs, and is worn by atmospheric agencies into the most fantastic shapes. Above it are sands, clays, sandstones of every texture and coal beds, one of which, near the summit of the hills, has been burned, baking and melting the superincumbent beds. I found in several layers the greatest abundance of deciduous leaves, and among them a fine Palm leaf, probably the same species which occurs in the coal beds on the Upper Missouri, named by Dr. Newbury *Campbelli*. There is also a thin seam near one of the coal seams made up of a small species of *Ostrea*.

The railroad passes down the Bitter creek valley which has been run through the tertiary beds, and on each side high walls can be seen inclining at low angles. As we pass down the valley toward Green river, the inclination brings to view lower and lower beds. These are all plainly marine tertiaries, while an abundance of impressions of plants are found everywhere. No strictly fresh water shells occur, but seams of *Ostrea* of various species. There are also extensive beds of hard tabular rocks which would make the best of flagging stones. On the surface are excellent illustrations of wave ripple marks, and at one locality tracks of a singular character; one looking as if it had been made by a soliped. It resembles the tracks of mules on the soft bottom ground. Others seem attributable to some huge bird; another to some four-toed Pachyderm. I obtained specimens and careful drawings of these tracks.

In the field report some detailed sections of these tertiary beds will be given. Yet I am convinced that local sections are not very important. The character is so changeable that two sections taken ten miles apart would

not be identical, and in some cases not even very similar. The more recent the age of formations the less persistent seem to be their lithological characters over extended areas.

Although the coal beds seem to be abundant everywhere along the line of the road in the lower tertiary deposits, they have been wrought as yet in few localities. Near Point of Rocks Station, about 45 miles east of Green river, one of the best coal mines I have yet seen in the West has been opened, and Mr. W. Snyder, the able Superintendent of the Union Pacific Railroad, has ordered a side track to be laid to it about a quarter of a mile long. Five coal beds have been opened in a vertical height of 80 feet. The lowest is about 100 feet above the bed of the creek. They are respectively 5, 1, 4, 3 and  $6\frac{1}{2}$  feet thick. The five foot bed is the most valuable, and as the strata are nearly horizontal it can be worked with ease and free of water. The hard, compact coal is pitched down the sides of the hill more than a hundred feet without being broken by the fall. It is purer and heavier than any coal I have yet seen west of the Laramie mountains. The other beds already opened will yield moderately good coal. Several other beds are in these hills which have not yet been examined. Near the summit of the hills, above the coal beds, there is a seam six inches thick composed entirely of oyster shells, about the size of the common edible oyster, but of a distinct and probably undescribed species.

Another bed of coal has been opened about 28 miles west of the Point of Rocks, at Rock Spring. It is about 4 feet thick, with a bed of sandstone at the bottom and a slaty clay roof. It cannot be worked to advantage.

Scattered all through the coal-bearing strata are seams and concretions of brown iron ore in abundance, sometimes persistent over extensive areas, and varying from 4 to 12 inches in thickness. The ore occurs mostly however in a nodular form, and much of it can be made of economical value when there is a demand for it. There are also numerous Chalybeate and Sulphur springs with excellent medicinal properties.

Near Rock Springs fresh water beds again incline nearly west  $6^{\circ}$  to  $10^{\circ}$ , but apparently different from those between Creston and Bitter creek.

The beds exposed at this point are made up of drab clays, sometimes a little sandy, with heavy beds of gray and rusty yellow easily disintegrating sandstones. There are also in the clay beds quite thick beds of coal which have ignited spontaneously and baked the superincumbent layers, in many cases melting the rock. There is very little vegetation on these hills, only now and then a dwarf cedar.

Near the summit of the hills there is a thin layer of limestone composed of an aggregate of small *melanias*.

From Rock Spring to Bryan the rocks present a peculiar appearance, occurring mostly in thin laminæ or layers like slate. There are 300 to 500 feet of these drab gray laminated shales, and above them, capping the hills about Green river, are from 300 to 500 feet of rusty yellow shales, which are weathered into castellated forms.

Near the junction of Bitter creek and Green river there is a bed of very singular bituminous earth which has excited much attention. It has been used as a fuel and burned so readily in stoves, that some people valued it more than true coal; but it is not now much used. An analysis shows that it is an inferior fuel.\* The bed is usually about 4 feet thick, but sometimes only 2 or 2½. It is often parted by several thin seams of shale. These Green river shales or slates as they might be called, must contain some calcareous matter, although not very fossiliferous. Possibly a more careful study will reveal a greater variety of animal and vegetable forms.

In the same cuts between Green river and Bryan, a distance of about 13 miles, great quantities of fossil fishes occur in a kind of chalky slate. Quite perfect impressions are formed upon the surfaces of the slates, presenting the appearance of having been preserved in quiet waters. Indeed all the Green river rocks may be said to possess a soft chalky character. At Bryan some fine specimens of fish were obtained from a well about 60 feet below the surface.

On the distant hills of this locality are layers of a chalky limestone which would make excellent lime and is now used as a building stone. It has the appearance of oolite, and in fact is made up of an extinct undetermined species of *Cypris*. About 7 miles west of Bryan we have :

4. Yellowish chalky laminated beds, very thinly divided.
3. Thin layers of gray chalky limestone filled with fresh water shells like *Corbula*.
2. Rusty indurated sandstone, somewhat shaly.
1. Gray shale.

Many of the layers in bed No. 3 are made up almost entirely of a small bivalve shell.

About 2 miles above Green River Station the river cuts through a great thickness of fine sand and gravel showing, on the slope and bottoms a vast deposit of drift. Much of the shale in this region has a greenish tinge, and the river in passing over them seems to have taken up some of the green coloring matter, so that the water has a peculiar green color and hence the name.

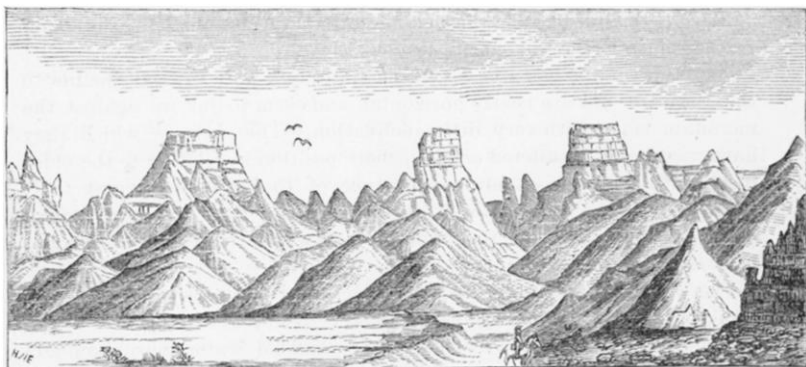
From Bryan to a point about 10 miles west of Fort Bridger the entire surface of the country is covered with buttes of every shape, cones,

\* Mr. Carson's analysis of a specimen of this bituminous earth gives the following constituents :

Silicic acid,	18.58.
Sulphuric acid,	3.88.
Sesquioxide of Alumina,	8.14.
Sesquioxide of Iron,	2.19.
Lime,	14.11.
Magnesia.	7.11.
Carbonic acid,	17.40.
Water,	2.90.
Volatile Matter,	22.25.
Fixed Carbon,	3.73.

pyramids, and long ridge-like hills which show a vast amount of erosion. Indeed the portion about Church Butes is precisely like the Manvaissettes or Bad Lands of White river.\*

FIG. 4.



In a cut along the railroad nearly opposite to Church Butes there is a bed formed of clay filled with small kidney shaped masses of fine bluish clay, the whole filled with beautiful specimens of *Unios*, *Puludinas* and other fresh water shells. There are also in the same cut layers of greenish clay much indurated, flesh colored concretionary and rusty drab sandstone.

About 6 miles west of Carter's Station a cut in the road reveals a tough plastic dark gray clay, and at the top of the cut a bed of flinty concretions filled with small seams of chalcedony. The whole country is paved with small water worn pebbles, mostly of opaque flint and some of them exceeding 4 or 5 inches in diameter. Over a belt about 10 miles wide from east to west and of unknown length from north to south, there are the greatest quantities of moss agates. I am inclined to the opinion that they originated in thin irregular seams in this recent tertiary formation; probably somewhere south of Church Butes. The origin of all this drift is evidently local and it is most probable that the transporting power had its origin in the Utah mountains. These tertiary beds are all nearly horizontal, inclining not more than  $1^{\circ}$  to  $3^{\circ}$ .

At South Bend Station there is a layer of silicious limestone filled with small *Melanias*, which are entirely changed into chalcedony. Some *Unios* also occur. The bed below it is composed of ashen gray shale a little arenaceous; then comes a silico-calcareous layer. Above the shell seam

\* The geologist can compare the following illustration of the "Bad Lands" of White river, Dakota, with Fig. 4, which is engraved from a photograph taken from nature, of Church Butes. The peculiar features of the weathered hills in this region bear a striking resemblance to those on White river.

is a great thickness of shale, capped with a kind of conglomerate made up of rounded pebbles and concretions, with here and there a *Unio*. In the south and east, 75 miles distant, we can see a range of snowy mountains, Minetah; and the intermediate country is covered with rugged tertiary bluffs. To the north, 100 to 150 miles away, the Wind River range is visible, and this interval is also occupied by the same rugged hills.

At Church Buttes a remarkable undescribed species of turtle was found projecting from the hill sides.

The beds of this basin near Church Buttes and Fort Bridger incline to the eastward, but are nearly horizontal, and seem to jut up against the mountain sides with very little inclination. The style in which they have weathered or suffered erosion, their position in relation to the older formations, and the general appearance of the surface, suggest their identity with the White River formations. But they are more arenaceous. I am inclined to the opinion that while they are independent basins they were synchronous.

The western rim of this recent fresh water basin is well defined at Quaking Asp ridge. Everywhere here the examples of erosion are displayed on a tremendous scale, and the rounded water worn boulders almost pave the ground. The west sides of the hills are quite abrupt, and are covered with the worn rocks; while the eastern sides slope gently down in long ridges; showing the direction from which the forces have acted as well as their local character; that they originated somewhere in the direction of the mountains, and by scooping out the valleys, strewed the surface with rocks.

Near Fort Bridger, and west to Quaking Asp Summit, there are in the recent tertiary formations several beds of the reddish grit which give its peculiar variegated character to much of the surface in this part of the West. In the cuts of the railroad are shown numerous beds of brick red and purplish clays and sands. The inclination of the beds just on the western margin of the basin is  $3^{\circ}$  to  $5^{\circ}$ . There are 100 to 150 feet of reddish indurated clays, slightly arenaceous, with some light brands, and one or two layers of gray sandstone; above this, 100 feet or more of light gray arenaceous material, with some hard layers of sandstone; then irregular harder layers of sandstone, sometimes concretionary, projecting from the sodded hills, and many of the peculiar features of the scenery are due to their existence.

After passing Quaking Asp Summit westward we come into a region underlain by a distinct series of formations of older date than those at Fort Bridger, and in many cases nearly or quite vertical. The same dip is again to the westward.

About 20 miles west of Fort Bridger there is a fine soda spring yielding the most delicious water. Judging from a deposit near the spring of what appears to be limestone, the water must hold lime as well as iron, &c., in solution. Probably it will be a place of resort at no distant day.

On Bear river there are several outcroppings of coal. The principal one by the side of the railroad near the station is nearly vertical, en-

closed between beds of drab clay, and separated into two members by a clay parting of from 8 to 10 feet thick. There is probably an aggregate of from 12 to 15 feet of good coal. The dip is towards the northwest  $60^{\circ}$  to  $80^{\circ}$ . On the upper side, above the drab clay, there is a bed of rather soft gray sandstone 50 to 100 feet thick. Below, are beds of rusty sandstone, clay, and indurated arenaceous clay, yellowish, drab, reddish and gray.

In a railroad cutting, about a mile east of the coal mine, are 25 to 50 feet of drab indurated clay, covered with 150 to 200 feet of ferruginous and gray sandstone dipping north-west. The lowest beds shown here look like cretaceous clays of No. 2; and in some of their slaty layers are an abundance of fish scales, a species of small oyster and a shell like an *Inoceramus*. These black plastic clays, are undoubtedly cretaceous and lie below the coal. The strata enclosing the coal are evidently marine, for all the organic forms thus far discovered seem to belong to marine types. There is also an oil spring in Bear River valley in which parties are sinking a shaft. The whole country exhibits abundant signs of drift action, and the hills as well as the valleys are paved with worn rocks. Between Bear and Sulphur creeks, there is a fine plateau 40 to 50 feet high, covered with sage—*Artemisia tufida*, and as smooth as a table. The soil in the bottoms of the streams is most fertile; if irrigated, vegetables of all kinds grow well, and there is abundance of water for that purpose.

On the right side of Bear river, 10 miles below the station is, Medicine Butte, which must be 800 to 1000 feet high above the bed of the creek. It is undoubtedly composed for the most part of the strata of the coal series, which I am inclined to regard as of older tertiary age, although the evidence is as yet conflicting.

Passing westward from Bear Creek Station, over beds nearly horizontal or inclining at a small angle, we suddenly come to an upthrust of rocks, called the Needles, dipping east or south-east  $25^{\circ}$  to  $35^{\circ}$  or  $40^{\circ}$ . This is a more remarkable exhibition of massive conglomerate than any I have ever seen further east. The rocks project their summits in the shape of sharp pointed peaks to a height from 300 to 500 feet above the road. Some of the worn masses which compose the conglomerate are an aggregation of worn pebbles, proving that a portion of the materials were derived from some still older conglomerate. Sometimes there is a thin local seam of coarse sand containing only a few pebbles, but the whole mass, from 500 to 1000 feet thick, is in the main a coarse conglomerate made up of water worn rocks varying in size from the smallest pebble to boulders a foot in diameter. The pebbles are mostly flint, mixed with a few of sandstone; rocks of modern data being comparative rare. This seems to be a local outburst of the conglomerate through a vast thickness of variegated sands and clays which inclines westward  $40^{\circ}$  to  $60^{\circ}$ . The trend is a little west of north. These "needle rocks" are near Yellow Creek Station, and the ridge of upheaval extends down from the Minetah range. In the vicinity of the mountain ranges such

local dips are common, and keep to no regular direction; but far distant from the source of power the ridges are comparatively regular.

From the hills about a mile west of Yellow Creek Station we have the first and most extended view of the country I have ever seen in the West. We can examine objects with considerable distinctness on a clear day for a radius of 50 to 100 miles in every direction, over a most rugged surface, with high ridges and deep gorges, the strata showing red, yellow, gray, and in fact every variety of color. Other beds are composed of quite light colored sandstone.

From Fort Bridger westward one of the most interesting phenomena is the favorable change that takes place in the vegetation of the surface. Broad plains and hill slopes covered thickly with grass, with comparatively little sage, is now the rule. Patches of quaking asp appear here and there and along the streams are fringes of cotton wood.

About 3 miles west of the Needles there is an upheaved ridge carrying a bed of white limestone, with streaks of chaledony in it resembling those of the White River tertiary limestones, and dipping nearly east at an angle of  $20^{\circ}$ . After leaving this point the rocks, again nearly horizontal, have for the most part a prevailing reddish tinge, with alternations of reddish indurated clays, and gray and reddish sandstones. The harder layers form quite abrupt bluffs 150 to 200 feet high all along the streams or valleys. In a tunnel at the head of Echo cañon, where the beds have been excavated by the Union Pacific Railroad Company, the base is a red indurated clay, slightly arenaceous, with bands of hard sandstone of a greenish tinge; above this, a red grit, much indurated, but becoming less so as we approach the summit. At Echo Station there are high bluffs of the red grits, with gray sandstones; but the prevailing color of all the rocks in Echo cañon from source to mouth is reddish or dark purple. The excavations for the grading of the railroad are extensive in this region and give a clear idea of the succession of the beds; but there is a great uniformity in the composition of the rocks. The sandstones are gray or yellow, and always yielding readily to the weather, wearing into all sorts of fantastic shapes, full of holes and caves, projecting points and pillars. The hills are covered with a considerable amount of loose material, worn rocks, &c. The valleys are also covered with a heavy superficial deposit.

From Bear creek to Echo Canyon Station, 20 miles, most of the way is over the red grit beds. The railroad runs directly down the Echo valley from its source to its junction with the Weber valley. Its scenery is wonderful from its general ruggedness; the water is excellent; the grass is good and all the valleys are susceptible of cultivation. Timber, though scarce everywhere, is more abundant than in localities farther to the east.

Passing down Echo Canyon from Hanging Rock Station to the mouth of Echo valley, bluffs of massive sandstone rise upon the right to a height of from 400 to 1000 feet, colored gray and yellow, yellowish purple and brick red, and containing some conglomerate.

A mile below Hanging Rock a drift into the bank 20 feet beneath a bed of conglomerate, discovered six inches of carbonaceous clay between two beds of ash colored, somewhat sandy, indurated clay, each about 6 feet thick. Below the coaly layer there are 2 inches of a material, which an analysis shows to be composed of Water 2.62, Volatile Matter 73.92, Sesquioxide 1.41, Lime 0.87, Magnesia trace, Sulphuric acid 0.37, Phosphoric acid a trace, Silica 59.14—99.80.

From the mouth of Echo up the valley the rocks seem to form a sort of gentle anticlinal for about 10 miles and then the inclination is reversed. The general dip however is  $5^{\circ}$  to  $15^{\circ}$ , nearly north-west; but for 6 miles below and 3 miles above Hanging rock it is increased to  $25^{\circ}$  and even to  $35^{\circ}$ .

This formation, which differs somewhat lithologically from any with which I am acquainted, must have an aggregate thickness of at least 3000 feet. The conglomerate portion must be at least 1500 feet in thickness. It includes beds of coal, and shows a few fossils, which are all either impressions of deciduous trees or marine shells.

Near Coalville, a little town in the valley of Weber river, 5 miles above the mouth of Echo creek, coal outcrops several times. At Spriggs' opening the dip is  $20^{\circ}$  or  $30^{\circ}$  east; and the coal bed about 15 feet thick; capped with gray sandstone, much of it charged with pebbles. I was informed that in other places this pebbly sandstone rests directly on the coal bed. A few hundred feet from Spriggs' opening, a shaft to strike the same bed has been sunk 79 feet deep, through 12 feet of gravel and sand, into black clay growing harder downward, and holding numerous specimens of a species of *Inoceramus*, *Ostrea*, and *Ammonites*, showing that the black clays are certainly of cretaceous age. If these beds do actually lie above the coal as the dip would indicate, then this formation of doubtful age, extending from Quaking Asp Summit to Salt lake, must be cretaceous, and some of the finest coal beds in the West are in rocks of that age.\*

The Weber river flows directly west and the rocks incline in a sort of half circle between north and south. Several beds of massive sandstone cap the high hills, and between them are layers of clay with a reddish tinge. I was informed that there were in this section 6 or 7 beds of coal varying in thickness from 18 inches to 15 feet.

Passing down the Weber valley the dip would carry down the Coalville coal beds, in a distance of 5 miles, that is, at Echo City, to a depth of from 1200 to 1500 feet beneath the surface. So that the coal area that can ever be made available for economical purposes in this region must be very limited.

An interesting feature along the Weber river is its terraces. Near Echo City there is a rather narrow bottom near the river; then an abrupt ascent of 30 feet; then a level plain or bottom of 200 to 400 yards; then a gentle ascent to the rock bluffs. The summit of the first bluff at Echo is 500 feet high; it then slopes back to the plains beyond.

Passing down the Weber valley, about a mile below Echo Station, the beds begin to dip  $25^{\circ}$  N. E. The whole valley is filled with rounded

[\* Confirming the published opinions of Dr. Le Conte and Dr. Newberry.—EDITOR.]

boulders, some of them 3 to 4 feet in diameter. The Weber river throughout the greater part of its course seems to plough through a monoclinal valley; but just before reaching the entrance of Lost creek it seems to pass along a local synclinal valley. A long ridge of conglomerate extends down from the direction of the Wasatch mountains, nearly north-east and south-west, inclining nearly north-east  $5^{\circ}$  to  $10^{\circ}$ . At this point, the Weber, instead of continuing in the synclinal valley, cuts through the ridge, isolating a portion about half a mile in length and forming a huge chasm, or gorge, which is called here the Devil's Gate. After passing through this ridge, the Weber receives Lost creek, and makes an abrupt bend to the southward; and here are exposed an immense thickness of the older rocks in a nearly vertical position. These rocks extend down the Weber river four miles or more, when the beds abruptly change from the nearly vertical position to a nearly horizontal one.

Commencing near the "Narrows," or the mouth of Lost creek, we have a considerable thickness of the jurassic limestones and marls, dipping  $70^{\circ}$  or  $80^{\circ}$  north-east, of a bluish ash color, very hard and brittle, cleaving into thin layers, and fracturing in every direction, so that the sides of the hills are covered to a great depth with its debris. Then comes a series of mud shales, with ripple marks, some layers of very white sandstone, and a thick bed of hard red sandstone, destined to take the highest rank among the building stone of Utah. It can be easily wrought into fine forms for culverts, fronts for buildings, caps and sills, &c. Then comes a vast thickness of gray, and dark gray, more or less cherty, limestones, which are probably carboniferous; and below these again a very hard silicious rock, oftentimes massive, which I referred to the Potsdam period, portions of which are filled with holes at right angles to the layers, very similar to much of the Potsdam east of the Mississippi pierced by *Scolithus linearis*. In this quartzose group there is a bed of shaly limestone, 6 to 10 feet thick. A few indistinct molluscs, were observed in the limestones and the mud shales.

The distance from the mouth of Lost creek to the end of the nearly vertical series of rocks is about three miles. So that we have here a thickness of strata not much less than two miles from the top of the Jurassic downwards so as probably to include the Silurian.

At the mouth of Lost creek, there is a remarkable example of non-conformity in hills of different ages. The reddish conglomerate rests directly upon the upturned edges of the vertical beds described above, and it is an important question what has become of all the intermediate beds, containing the coal, which are so conspicuous about 5 miles above Echo city.

Descending the Weber from the "Narrows" we find some of the most remarkable rugged scenery in the west. The walls are very noticeable, and are formed of two beds of limestone, projecting from the sides of the valley, at right angles, from between which 10 or 12 feet of loose material has been washed out. Near the tunnels the rocks on the left side of the Weber dip about  $10^{\circ}$ , nearly north, while on the other side the strata incline in the opposite direction  $3^{\circ}$  to  $5^{\circ}$ , as if the valley was anticlinal.

Then again the valley would appear to be monoclinical, the strata on the right side of the river inclining  $20^{\circ}$  south, and on the opposite side, though presenting a nearly vertical front, inclining south also. A little farther on down the valley, and on the right side of the river, come beds of red sandstone; below these again gray sandstone, with a reddish tinge, the red sandstone dipping east  $12^{\circ}$ ; while on the opposite side of the river, the hills are open, rounded and grass covered.

The cherty crinoidal limestone extends to Morgan city and generally disappears. The red sandstones are seen among the foot hills.

At Morgan city, we come out of the principal cañon of the Weber, into a broad open bottom, filled with little villages and farm houses. The soil is of great fertility. The hills on either side are smoothed off and covered thickly with loose material and vegetation. The high vertical exposures all disappear. The Wasatch range seems to trend nearly north and south; even the foot hills of this range are so smoothed off and covered with drift and then with grass, that the underlying rocks are not to be seen. The industry shown by the Mormons in this valley is worthy of all praise. The little streams are made use of to irrigate the rich bottom lands, which produce abundantly, and the houses look neat and comfortable. Fruit cannot be raised to any extent in the Weber valley. The varieties of trees are confined mostly to the bitter-cotton-wood, although from Echo city down, we meet with a small dwarf, oak-box, elder, striped maple, and choke-cherry.

Just below the little village of Enterprise, I saw in the hills rocks composed of an aggregate of quartz pebbles, the whole mass looking like the Potsdam. Still farther down, we come to feldspathic rocks, indicating that the dip of the gneissic beds of the Wasatch range is westward. The Wasatch range is composed of gneiss so far as the rocks can be seen along the Weber. The rocks are beautifully banded everywhere. There are also coarse aggregations of quartz and feldspar with large masses of tourmaline; and all through the gneiss are seams of feldspar and quartz of various thicknesses.

The evidence is quite clear that from Morgan city to the entrance of the Wasatch Kanyon stretched a lake, the waters of which must have filled up the valley, rounded off the hills and covered the sides of the mountains with loose debris. Along the sides of the Kanyon of the Wasatch,  $4\frac{1}{2}$  miles long, are thick deposits of loose sand interspersed with water worn boulders in many places. These deposits have been cut through in making excavations by the railroad, and the lines of current deposition are curiously well marked. About half way through the kanyon, there is a sudden bend in the Weber river, by which a small portion of one of gneissic ridges is cut off. Opposite this ox-bow, a kanyon descends the mountain side, down which a vast quantity of loose material has been swept, filling the channel of the river with local drift, and probably driving the current through the gneissic ridges. The Weber river, if its channel were straightened, would run through this deposit of drift, which is about 30

feet thick ; instead of which, it makes a bend and cuts its way through a massive gneissic ridge.

Extensive deposits of whitish, fine blue and rusty yellow sandstones, hard enough for building purposes, with flesh colored marls, probably of pliocene age, and resembling very closely in many respects the more recent tertiary beds along the Platte, occur in this valley. These recent beds dip east or south-east. We thus learn that some of the later movements in the elevation of these mountain ranges have been of comparatively modern date. Terraces continue to show themselves the entire length of the Weber river, and they are probably synchronous with those which surround the basin of Salt Lake valley.\*

Fig. 5.



After emerging from the Wasatch Kanyon of the Weber valley, we pursued a southerly course along the base of the Wasatch range to Salt Lake city. For 20 miles or more, all the unchanged rocks have been worn away from the flanks of the mountains or completely concealed by debris. All over the gentle slopes at the foot of the mountains are strewn masses of rocks ; all gneissic and evidently from the central parts of the mountains. Terraces distinctly surround this basin everywhere. There is one large one, with two or three smaller ones, on the sides of the mountains, and from the lowest one downwards, the surface slopes gently to the lake. I was informed that the lake had risen 9 feet vertically since 1868, and of course the water has aggressed upon the land to a great distance. I have heard no explanation of this phenomenon. All the lakes in the west are said to be rising more or less.

\* This illustration from a sketch by Mr. F. W. Meek of the terraces along the Missouri river between Council Bluffs and Sioux City, will apply equally well to Helena or Salt Lake valley ; and they are doubtless synchronous in age. In the sketch, the distant high hills are composed of yellow marl or "loess," the terraces the same, and the bottom of rich vegetable mould.

The carboniferous limestones begin to make their appearance along the flanks of the mountains about 10 miles north of Salt Lake city, and continue to a great or less extent all around the rim of the basin.

On the flanks of the mountains, east of the city, are the red beds (jurassic?); probably a careful study would reveal jurassic, cretaceous, and possibly even tertiary beds. President Young has long since offered a large reward to any one who would discover workable beds of coal within a reasonable distance of the city, and a thorough search has been made for them, but thus far without success. A bed of coaly clay only has been found near the city in the mountains. All the coal used in the valley is transported in wagons from Coalville, on the Weber. The best of red sandstone for building purposes is brought from red sandstone cañon, just east of the town. I am inclined to believe that it is carboniferous. The beautiful gray granite which is used in the construction of the Mormon temple is brought from Cottonwood valley in the Wasatch mountains. It is composed of white feldspar, quartz and black mica.

The surface of Salt Lake valley has been rendered fruitful by the industry of the Mormons. Like the greater portion of the west, it was originally a vast sage plain. Now by irrigation all kinds of cereals and roots grow luxuriantly, and there are no better apples, peaches, plums, grapes, &c., raised in America. It may eventually become a vine growing region.

Following the stage road eastward, 16 miles from Salt Lake city to the Brewery at the mouth of Parley's Canyon, we reach the foot of the mountain, over sand beds which are probably of post-pliocene age. Here a little stream cuts through the sand beds, exposing a vertical bluff 200 feet high, composed of some fine sand, horizontally stratified and overlaid with a great thickness of water worn pebble conglomerate. There are indications all along the flanks of the mountains, that nearly or quite all the formations already recognised as far west as this point are here represented. At the entrance of the canyon, the carboniferous limestones dip north-east  $70^{\circ}$  to  $80^{\circ}$ ; over them lie the purple and red sandstones and rusty yellow layers; and under them reddish shales. Beneath these shales an immense thickness of dark gray silicious rock stands nearly vertical. All this vast thickness of older rocks, in appearance semi-metamorphosed, are undoubtedly the counterparts of the series described in the Weber valley just below the entrance of Lost creek.

The road passes up a monoclinal valley between the ridges of silurian (?) rock, having a brittle fracture, and the monoclinal slopes are covered with debris. No gneissic rocks are noticeable along this road.

Before reaching the summits, in fact soon after we begin the ascent, we come to the conglomerates and sandstones which accompanied us down the Echo and Weber valleys. Near the summit all the hills are rounded by erosion and grassed over, and water-worn boulders are scattered about here and there, so that the underlying rocks are partially concealed. Just beyond the summit we arrive at a broad open exposure in the valley of the stream called Parley's Point, half a mile wide, and about 7000 feet

above sea level. Settlements are numerous all along the road ; but while there is very good grazing, few of the cereals will grow.

All the rocks on the eastern slope incline at a greater or less angle apparently towards the east. Just as we enter Silver Creek valley, we come to numerous upthrusts of partially changed sandstones and conglomerates, the first indications that we get along our route of the neighborhood of igneous rocks. Some of the masses of rock which go to make up the conglomerate are of great size, very compact and of a steel gray color, and are enclosed in a gray siliceous paste ; but whether large or small, all are angular. The formation looks much like that near South Boulder creek, near Denver.

Passing down the valley of Silver creek, we soon emerge into the valley of the Weber. We come to the hills enclosing the coal which dip down the valley at angles of from  $20^{\circ}$  to  $50^{\circ}$ , and of course the belt along which the coal beds are exposed is very narrow. Five or six beds as I have before said, varying in thickness from a few to 15 feet, are reported. I heard also that about 4 miles from Mr. Sprigg's opening, a bed of fossil oysters had been seen above the coal. That these coal strata are of marine or estuary character I have no doubt ; but the limited time given me for their study prevented me from securing such positive evidence as is desirable ; and as this formation occupies a vast area west of Fort Bridger, it seems all the more important to fix its geological position. That it is not older than the cretaceous we know by the occurrence of leaves of deciduous trees, and the black plastic clays of No. 2, holding quantities of fragments of fish-remains.

I will now recapitulate briefly the principal geological formations along the line of the Union Pacific Railroad from Omaha to Salt Lake city.

The Upper Coal Measure Limestones are seen at Omaha, near the water's edge, and quarried all along the Platte nearly to the Elk Horn river.

The Lower Cretaceous rusty sandstones of No. 1, overlap the Upper Carboniferous limestones about four miles above the mouth of the Platte, and extend to the mouth of the Loup Fork ; but the yellow marl deposit or loess, conceals for the most part the underlying rocks. A fine yellowish sand, of the same age, or a little less recent, overlaps the cretaceous near Columbus.

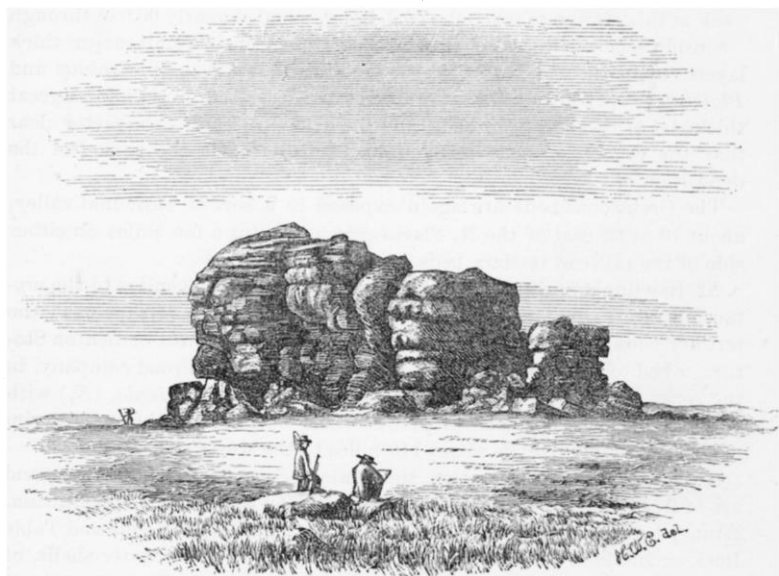
The chalky limestones of No. 3, with the characteristic *Inoceramus problematicus*, here and there crop out, and some obscure exposures have been detected in the Pawnee Reservation, 15 or 20 miles up the Loup Fork.

This fine yellowish sand soon gives place to the Pliocene beds of the Platte, Loup Fork and Niobrara rivers, indurated marls, sands, or sandstones, which continue on as far as the margin of the Laramie range of mountains, 530 miles west of Omaha, that is, for nearly 430 miles along the line of the railroad. In the grand anticlinal of the Laramie range, which I have already described, they sometimes repose with a slight discordance on the older rocks ; sometimes, as near the Laramie peak, they rest directly on the syenites, and entirely conceal, for a distance of 40 or

50 miles, all the unchanged rocks of older date ; but a careful study of the eastern flank, from Red Butes to Long's Peak, will reveal all the formations that are known to exist in this part of the west, inclining from the sides of the granitic nucleus at various angles.

The railroad then for 40 miles passes over and cuts through a great variety of Syenites ; some compact, beautiful building stones, almost equal to the Scotch Iyenites, but the greater part ferruginous and easily disintegrating on exposure.\*

Fig 6.



On the west side of the Laramie range, we pass across the upturned edges of the counterparts of the various formations seen on the eastern slope. From Laramie city to Salt Lake, formations of different ages continually appear and disappear. The Cretaceous formations occupy the country for 60 miles from Laramie city nearly to lake Como.

Genuine Jurassic beds, with characteristic fossils, are here exposed for a short distance, in an anticlinal valley, along which the railroad passes. *Belemnites densus* are in great numbers.

Cretaceous beds mostly No. 2, appear again west of Como.

Miocene coal beds overlay the cretaceous, just before reaching Carbon

\* These syenites weather into most beautiful forms resembling gigantic ruins, so that they have sometimes deserved their common appellation, of broken down temples, castles, &c. The sketch, (Fig. 5.) shows well the peculiar features which these piles of rocks assume through atmospheric influences. It is engraved from a photograph of a scene on the Laramie range, taken by Mr. Carbutt, photographer, of Chicago, Illinois.

Station, 80 miles west of Laramie. At Carbon where they are exposed to view, impressions of fossil leaves occur in the greatest abundance. The species are few and nearly all of them identical with those described by Dr. Newbury, from the miocene tertiary beds of the Upper Missouri. Some strata consist almost entirely of leaves, in a fair state of preservation, as if they had not been subjected to a great deal of drifting prior to deposition. Indeed, the trees themselves must have grown near the spot, to shed their leaves in such great abundance, just as we find leaves accumulated now in muddy bottoms. Dr. Newbury has identified from this locality, *Populus Cuneata*, *Populus Nebrascensis*, *Platanus Haydeni* and an undescribed species of *Cornus*. The Wyoming Coal Company's shaft sunk at this station to reach the coal, has descended nearly 60 feet through a considerable thickness of bluish-black arenaceous clay, in rather thick layers, upon the surface of which are great quantities of *Populus* and *Platanus*. Very nearly the same species are described throughout a great thickness of these tertiary beds, and the evidence seems to be pretty clear that the vegetation was nearly uniform throughout the period of the deposition of the coal strata.

The Cretaceous beds are again exposed in a sort of anticlinal valley, about 10 miles east of the N. Platte crossing. But a few miles on either side of the railroad tertiary beds are seen.

At Rawling's Springs, all the formations from the syenites to the cretaceous, are thrown up over a restricted area; 2 miles farther west, the tertiary beds again overlay. At Separation, 26 miles west of Benton Station, a bed of excellent coal has been opened by the railroad company, in the rocks over which *Platanus Haydeni* and *Cornus acuminata*, (N,) with other undetermined species of plants occur. This forms the eastern rim of a basin which extends about 110 miles to the westward.

Soon after leaving Separation, the strata becomes nearly horizontal, and are of fresh water instead of estuary origin. Beyond Bitter Creek Station, estuary beds reappear dipping east. At Washakie, Red Desert and Table Rock occur thick beds made up of an aggregate of fresh water shells, of the genera *Unio*, *Paludina*, *Limnea*, *Melania*, &c., At Black Buttes and Point of Rocks, a great abundance of impressions of deciduous leaves are found. At Black Butte Station, about 850 miles west of Omaha, I found in the coal strata *Sabal Campbelli*, N, *Rhamnus elegans*, *Cornus acuminata*, *Quercus aceroidea*, *Tilia antiqua*, with some undescribed species.

At Point of Rocks, an important coal station, about 14 miles farther west, I found *Platanus Haydeni*, *P. Nebrascensis*, *Cornus acuminata*, and *Magnolia teneraefolia*. In the vicinity of Elk mountain, along the overland stage road, in beds which I regarded as belonging to the older tertiary, and holding a position near the junction of the tertiary and cretaceous, and nearly or quite on a parallel with the lower tertiary beds near Denver, Colorado, I found *Platanus Haydeni*, *Quercus aceroidea*, *Magnolia teneraefolia*, with fragments of *Cornus* and *Rhamnus*.

Near Green River the eastern rim of what appears to be another tertiary basin commences, the beds having a gentle dip to the westward. Between

Green River crossing and Bryan Station, fine specimens of fossil fishes occur in rocks which resemble the Solenhofen slates. West of Bryan, fresh water shells of the genera *Corbicula*, *Limnea*, *Physa*, *Paludina*, *Melania*, and *Unio* occur in the greatest quantities. This basin extends to Quaking Asp ridge, 22 miles west of Fort Bridger.

We then come to a series of variegated beds, whose dominant color is red or reddish, of estuary or marine origin, with coal beds from 6 to 15 feet thick. These extend far westward to the Wasatch mountains, possibly farther. The evidence inclines one to regard them of cretaceous age, but they may be older tertiary.

In Weber valley there is an immense thickness of the older sedimentary rocks from the jurassic inclusive to the silurian inclusive, the thickness of which I estimated at from 5,000 to 10,000 feet.

The Wasatch range is composed of metamorphic rocks, mostly gneissic, which are well shown in the valley of Weber river for the distance of 4 miles.

The Union Pacific Railroad from Omaha to Salt Lake valley, a distance of nearly 1200 miles, really pass through metamorphic rocks but twice; first in crossing the Laramie range, a distance of 20 or 30 miles, and in the Weber valley through the Wasatch range, 4 miles. At Rawling's Springs, the syenites are seen on the north side of the road for a little distance, but not immediately along it.

It will thus be seen that over the vast region known as the Rocky Mountain district proper, the area that can be colored on a geological map as occupied by igneous or metamorphic rocks is comparatively small, while the more modern formations as tertiary and cretaceous, are met with everywhere even up to the summits of the loftiest ranges and sometimes covering them.

NOTE. The illustration, Plate 1, Fig. 2, Pulpit Rock, shows the high nearly vertical bluffs of conglomerate, at the entrance of Echo creek into the Weber river, Utah Territory. I am inclined to regard these rocks as older tertiary, from the fact that they lie along the coal beds of this region, but they may be cretaceous.

Twin Peaks, No. 1, Plate 1, form a part of a mountain range, enclosing Salt Lake valley. The terrace system is well shown, as described in the preceding paper.